| | Type | Hits | Search Text | DBs | Time Stamp |
|---|---|---|---|---|---|
| 1 | BRS | 42 | 360/323.ccls. | USPAT | 2003/04/02 09:20 |
| 2 | BRS | 105 | ((write or read) near2 head) and (protect$4 near5 discharg$4) | USPAT | 2003/04/02 09:21 |
| 3 | BRS | 241 | ((write or read) near2 head) and ((protect$4 or prevent$4) near5 discharg$4) | USPAT | 2003/04/02 10:00 |
| 4 | BRS | 221 | (((write or read) near2 head) and ((protect$4 or prevent$4) near5 discharg$4)) not 360/323.ccls. | USPAT | 2003/04/02 09:22 |
| 5 | BRS | 4 | ((write or read) near2 head) and ((protect$4 or prevent$4) near5 (electric near2 discharg$4)) | US-PGPUB; EPO; JPO | 2003/04/02 10:03 |
| 6 | BRS | 38 | ((write or read) near2 head) and ((protect$4 or prevent$4) near5 discharg$4) | US-PGPUB; EPO; JPO | 2003/04/02 10:10 |
| 7 | BRS | 144 | ((write or read) near2 head) and (shunt$4 same contact$4) | USPAT; US-PGPUB; EPO; JPO | 2003/04/02 10:11 |
| 8 | BRS | 418 | (head or sensor) and ((static$4 near3 (charge or discharge)) near2 (prevent$4 or protect$4 or shunt$4)) | USPAT; US-PGPUB; JPO | 2003/04/02 10:32 |

| | Type | Hits | Search Text | DBs | Time Stamp |
|---|---|---|---|---|---|
| 9 | IS&R | 3 | (("5108299") or ("4971568") or ("5163850")).PN. | USPAT | 2003/04/02 12:44 |
| 10 | BRS | 10 | 278024.ap. or 278063.ap. or 234917.ap. | USPAT | 2003/04/02 13:10 |
| 11 | BRS | 21757 | contact near2 resistance | USPAT | 2003/04/02 13:10 |
| 12 | BRS | 14574 | contact adj resistance | USPAT | 2003/04/02 13:10 |
| 13 | BRS | 103 | (contact adj resistance) and (Magnetic adj head) | USPAT | 2003/04/02 13:11 |
| 14 | BRS | 0 | (contact adj resistance) and (staticelectric adj discharge) | USPAT | 2003/04/02 13:12 |
| 15 | BRS | 151 | (contact adj resistance) and (electrostatic adj discharge) | USPAT | 2003/04/02 13:30 |
| 16 | BRS | 6 | (metal near3(contact adj resistance)) near3 ("omega." or ohm) | USPAT | 2003/04/02 13:21 |
| 17 | BRS | 7 | (metal near5(contact adj resistance)) near3 ("omega." or ohm) | USPAT | 2003/04/02 13:21 |
| 18 | BRS | 22 | (metal near6(contact adj resistance)) near6 ("omega." or ohm) | USPAT | 2003/04/02 13:39 |

| | Type | Hits | Search Text | DBs | Time Stamp |
|---|---|---|---|---|---|
| 19 | BRS | 16 | ((metal near6(contact adj resistance)) near6 ("omega." or ohm)) not ((metal near3(contact adj resistance)) near3 ("omega." or ohm)) | USPAT | 2003/04/02 13:22 |
| 20 | BRS | 42 | 360/323.ccls. | USPAT | 2003/04/02 13:30 |
| 21 | BRS | 36 | 360/323.ccls. and (voltage or volt) | USPAT | 2003/04/02 13:38 |
| 22 | BRS | 1 | 360/323.ccls. and (contact adj resistance) | USPAT | 2003/04/02 13:39 |
| 23 | BRS | 28 | (metal near8 (contact adj resistance)) near8 ("omega." or ohm) | USPAT | 2003/04/02 13:40 |
| 24 | BRS | 6 | ((metal near8 (contact adj resistance)) near8 ("omega." or ohm)) not ((metal near6(contact adj resistance)) near6 ("omega." or ohm)) | USPAT | 2003/04/02 13:40 |
| 25 | BRS | 2 | ((read or write) near2 (head or sensor or transducer)) and ((shunt$4 or deshunt$4) near2 rail) | USPAT; US-PGPUB; EPO; JPO | 2003/04/02 15:42 |

# Patent Assignment Abstract of Title

**Total Assignments:** 2

**Application #:** 10021956 **Filing Dt:** 12/17/2001 **Patent #:** NONE **Issue Dt:**

**PCT #:** NONE **Publication #:** 20020075610 **Pub Dt:** 06/20/2002

**Inventors:** Frank William Schadewald JR., Arnold Warren Johansen

**Title:** Disc drive shunting device

**Assignment:** 1

| **Reel/Frame:** | **Received:** | **Recorded:** | **Mailed:** | **Pages:** |
|---|---|---|---|---|
| 012765/0322 | 04/11/2002 | 03/29/2002 | 06/05/2002 | 4 |

**Conveyance:** ASSIGNMENT OF ASSIGNORS INTEREST (SEE DOCUMENT FOR DETAILS).

**Assignors:** SCHADEWALD, FRANK WILLIAM, JR. **Exec Dt:** 12/14/2001

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**Assignment:** 2

| **Reel/Frame:** | **Received:** | **Recorded:** | **Mailed:** | **Pages:** |
|---|---|---|---|---|
| 013177/0001 | 10/08/2002 | 08/05/2002 | 10/18/2002 | 466 |

**Conveyance:** SECURITY AGREEMENT

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Search Results as of: 4/2/2003 12:33:04 P.M.

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US006335263B1

(12) **United States Patent**
**Cheung et al.**

(10) **Patent No.:** **US 6,335,263 B1**
(45) **Date of Patent:** **Jan. 1, 2002**

(54) **METHOD OF FORMING A LOW TEMPERATURE METAL BOND FOR USE IN THE TRANSFER OF BULK AND THIN FILM MATERIALS**

(75) Inventors: **Nathan W. Cheung**, Albany; **Timothy David Sands**, Moraga; **William S. Wong**, Berkeley, all of CA (US)

(73) Assignee: **The Regents of the University of California**, Oakland, CA (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/535,658**

(22) Filed: **Mar. 22, 2000**

(51) **Int. Cl.**[7] .......................... **H01L 21/30**; H01L 21/46
(52) **U.S. Cl.** .......................... **438/455**; 438/458; 438/604
(58) **Field of Search** .......................... 438/455, 458, 438/586, 584, 604

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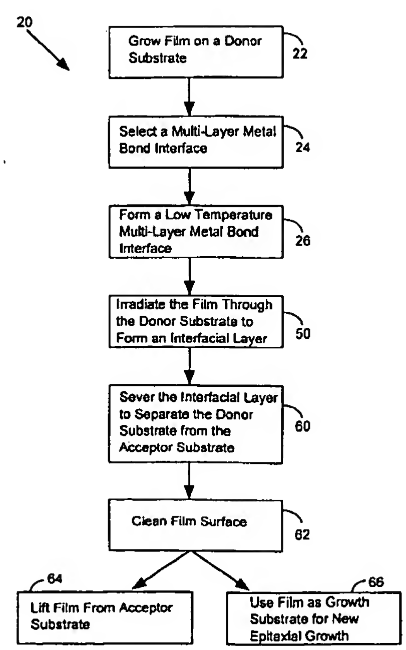
(74) *Attorney, Agent, or Firm*—Pennie & Edmonds LLP

(57) **ABSTRACT**

A method of forming a low temperature metal bond includes the step of providing a donor substrate, such as a crystallographically oriented donor substrate, including a sapphire donor substrate or a MgO donors substrate. The donor substrate may also be quartz or fused silica. A thin film is grown on a surface of the donor substrate. The thin film may be an oxide, nitride or Perovskite. The invention may be implemented using nitride thin films, including AlN, GaN, InN, and all of their solid solutions, alloys, and multi-layers. An acceptor substrate is then produced. The acceptor substrate may be Si, GaAs, polymers, such as polyimide, or stainless steel for use in microrobotics. A multi-layer metal bond interface for positioning between the thin film and the acceptor substrate is then selected. The multi-layer metal bond interface must satisfy a set of criteria, such as low temperature bonding, low resistance to shear stress, capability to adhere to the donor and acceptor substrates, and the ability to form a thin new bonded layer. A bonded layer is then formed, at a temperature below approximately 200° C., between the thin film and the acceptor substrate using the multi-layer metal bond interface. The donor substrate is then severed from the thin film to isolate the thin film for subsequent processing.

**31 Claims, 4 Drawing Sheets**



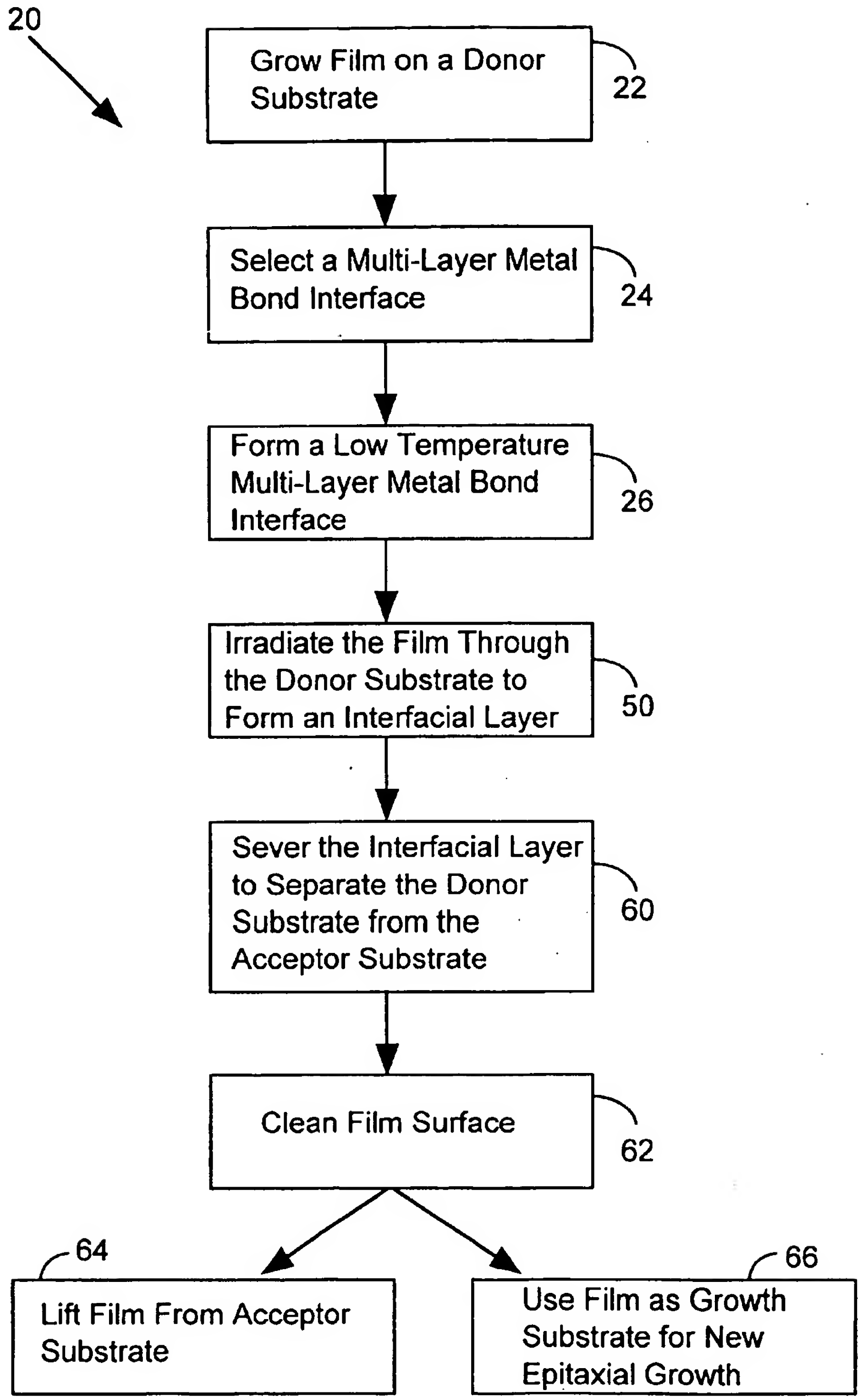

20
Grow Film on a Donor Substrate
22
Select a Multi-Layer Metal Bond Interface
24
Form a Low Temperature Multi-Layer Metal Bond Interface
26
Irradiate the Film Through the Donor Substrate to Form an Interfacial Layer
50
Sever the Interfacial Layer to Separate the Donor Substrate from the Acceptor Substrate
60
Clean Film Surface
62
64
Lift Film From Acceptor Substrate
66
Use Film as Growth Substrate for New Epitaxial Growth

Figure 1

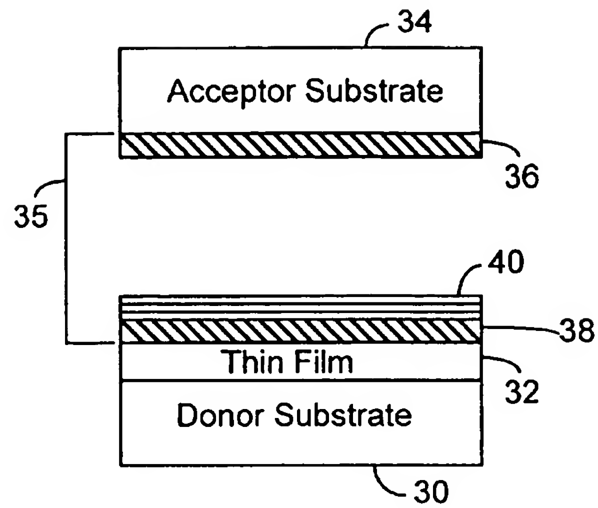



Figure 2

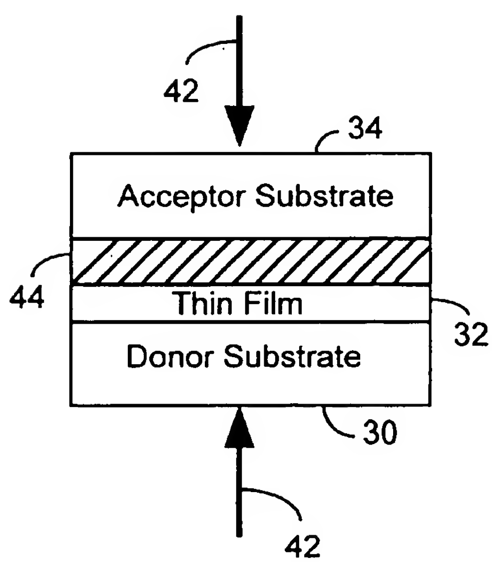



Figure 3

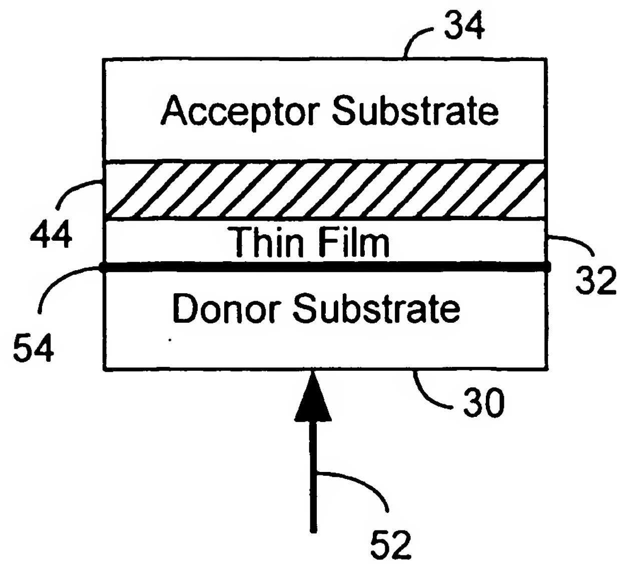



Figure 4

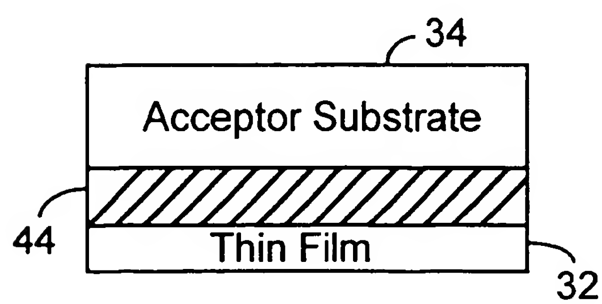



Figure 5

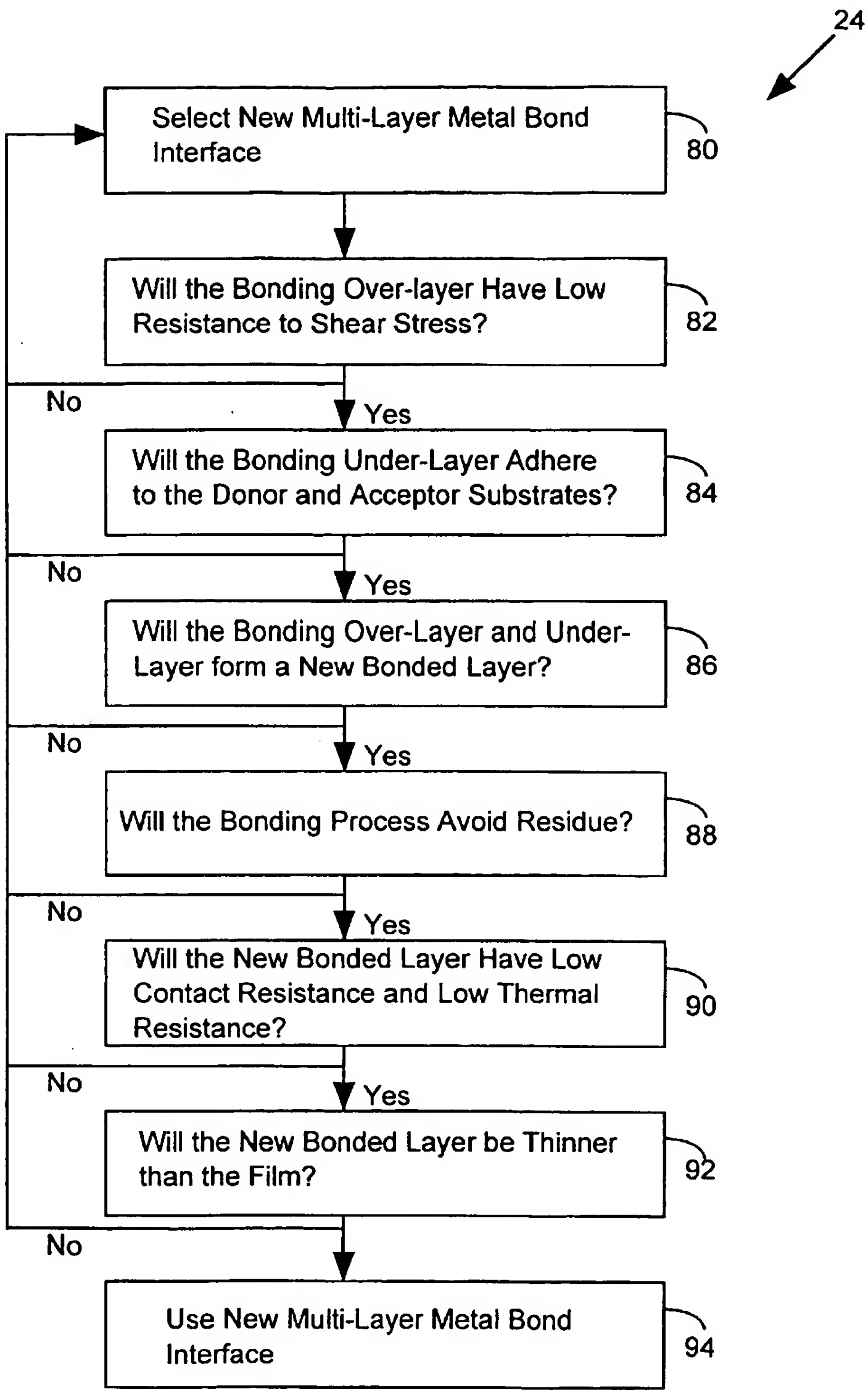

24
Select New Multi-Layer Metal Bond Interface
80
Will the Bonding Over-layer Have Low Resistance to Shear Stress?
82
No
Yes
Will the Bonding Under-Layer Adhere to the Donor and Acceptor Substrates?
84
No
Yes
Will the Bonding Over-Layer and Under-Layer form a New Bonded Layer?
86
No
Yes
Will the Bonding Process Avoid Residue?
88
No
Yes
Will the New Bonded Layer Have Low Contact Resistance and Low Thermal Resistance?
90
No
Yes
Will the New Bonded Layer be Thinner than the Film?
92
No
Use New Multi-Layer Metal Bond Interface
94

Figure 6

# METHOD OF FORMING A LOW TEMPERATURE METAL BOND FOR USE IN THE TRANSFER OF BULK AND THIN FILM MATERIALS

## RELATED APPLICATIONS

This application is related to U.S. Ser. No. 09/012,829, filed Jan. 23, 1998, entitled "Separation of Thin Films from Transparent Substrates by Selective Optical Processing", which has common inventors and a common assignee. The related application is incorporated by reference herein.

## BRIEF DESCRIPTION OF THE INVENTION

This invention relates generally to the handling of materials used in the electronics field. More particularly, this invention relates to a technique of forming a low temperature metal bond to facilitate the transfer of bulk and thin film materials used in the electronics field.

## BACKGROUND OF THE INVENTION

The intimate integration of thin film materials with disparate properties is required to enhance the functionality of integrated Microsystems. For example, combining laser diodes with low cost electronics necessitates the integration of III–V semiconductors with silicon. The materials integration can be done simply by direct deposition of the thin film onto the final substrate. In many cases, however, direct deposition involves substantial sacrifices in the microstructural quality, properties and performance of the thin film. In some cases, such as integration of piezoelectric electro-ceramic thin films with polymer substrates, the processing conditions (e.g., temperature and ambient) preclude direct deposition. In these instances, a bonding and lift-off approach may be required.

A bonding process involves adhering a heterostructure (e.g., a thin film) still on its growth substrate to a final micro-machined, patterned, and metallized substrate. To allow maximum flexibility for a wide range of material combinations it would be highly desirable to adhere to a number of constraints. For example, the bonding layer should have low resistance to shear stress at temperatures below 200° C. such that submicron surface asperities and particulates do not prevent full surface contact. It would also be desirable to have a bonding layer that is both adherent to the heterostructure and the final acceptor substrate. In addition, the bonding process should be performed in such a manner that it does not leave behind a low melting point phase or residue. Ideally, the resulting bond would have low electrical resistance and low thermal resistance. Finally, the bonding layer should be thinner than the thin film to be transferred, such that its properties do not dominate those of the transferred thin film.

If the foregoing constraints could be satisfied, the opportunities for integration of thin film materials with other systems would increase. More particularly, opportunities for the direct integration of thin films with novel substrate materials for improved device performance would increase.

## SUMMARY OF THE INVENTION

A method of forming a low temperature metal bond includes the step of providing a donor substrate, such as a crystallographically oriented donor substrate, including a sapphire donor substrate or a MgO donor substrate. The donor substrate may also be quartz or fused silica. A thin film is grown on a surface of the donor substrate. The thin film may be an oxide, nitride or Perovskite. The invention may be implemented using nitride thin films, including AlN, GaN, InN, and all of their solid solutions, alloys, and multi-layers. An acceptor substrate is then produced. The acceptor substrate may be Si, GaAs, polymers, such as polyimide, or stainless steel for use in microrobotics. A multi-layer metal bond interface for positioning between the thin film and the acceptor substrate is then selected. The multi-layer metal bond interface must satisfy a set of criteria, such as low temperature bonding, low resistance to shear stress, of durability to adhere to the donor and acceptor substrates, and the ability to form a thin new bonded layer. A bonded layer is then formed, at a temperature below approximately 200° C., between the thin film and the acceptor substrate using the multi-layer metal bond interface. The donor substrate is then severed from the thin film to isolate the thin film for subsequent processing.

An embodiment of the invention has utilized low temperature Pd—In metal bonding to bond GaN thin films onto Si, GaAs, and polyimide substrates. The Pd—In bonding layers form a $PdIn_3$ compound after pressure bonding at a temperature of approximately 200° C. Separation of the sapphire substrate from the GaN thin film can be achieved using a pulsed ultra-violet laser lift-off process. Thin film characterization by x-ray diffraction, scanning electron microscopy, and atomic force microscopy verify that the GaN retains its crystal quality before and after thin film separation and transfer. The technique of the invention creates opportunities for integration of GaN-based devices with other material systems. The "cut and paste" methodology of the invention may be used to combine GaN with other material systems that otherwise cannot be used in conventional growth processes. The technique of the invention allows direct integration of GaN with novel substrate materials for improved device performance.



## BRIEF DESCRIPTION 0F THE DRAWINGS

For a better understanding of the invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 illustrates processing steps performed in connection with the formation of a low temperature metal bond of the invention.

FIG. 2 is an exploded view of an acceptor substrate, a multi-layered metal bond interface, a thin film, and a donor substrate of the invention.

FIG. 3 illustrates an acceptor substrate, bonded layer, thin film, and donor substrate formed in accordance with an embodiment of the invention.

FIG. 4 illustrates the formation of an interfacial layer in accordance with an embodiment of the invention.

FIG. 5 illustrates a thin film isolated from its donor or substrate after processing in accordance with an embodiment of the invention.

FIG. 6 illustrates processing steps associated with the selection of a multilayer metal bond interface for low temperature metal bonding in accordance with an embodiment of the invention.

Like reference numerals refer to corresponding parts throughout the drawings.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a method 20 of forming a low temperature metal bond in accordance with an embodiment of the

invention. The method 20 includes the step of growing film on a donor substrate (step 22). For example, a GaN semiconductor thin film may be grown on a crystallographically oriented growth substrate, such as sapphire or MgO.

The next processing step is to select a multi-layer metal bond interface that can be used to form a low temperature metal bond (step 24). As used herein, the term low temperature means approximately 200° C. or lower. The details associated with an embodiment of this step are described below in connection with FIG. 6.

The next processing step is to form the selected multi-layer metal bond interface between the thin film and an acceptor substrate (step 26). FIG. 2 illustrates a donor substrate 30 with a thin film 32 grown thereon in accordance with step 22. FIG. 2 also illustrates an acceptor substrate 34. In one embodiment of the invention, the acceptor substrate 34 is Silicon. Positioned between the donor substrate 30 and the acceptor substrate 34 is a multi-layer metal bond interface 35. In the embodiment of FIG. 2, the multi-layer metal bond interface 35 includes an acceptor bonding under-layer 36, a donor bonding under-layer 38, and a bonding over-layer 40. In one embodiment of the invention, the acceptor bonding under-layer 36 includes a layer of approximately 100 nm of Pd. In one embodiment of the invention, the donor bonding under-layer 38 includes approximately 10 nm of Ti and approximately 100 nm of Pd. The Ti facilitates adhesion of Pd to a thin film, such as GaN. The bonding over-layer 40 may be formed with approximately 1000 nm of In. Preferably, the thickness of the Pd and In layers are chosen such that the ratio of Pd:In is maintained at 1:3 in order to form the compound $PdIn_3$ after completion of the bonding process. The ratio will also ensure total consumption of In so that no component of low-temperature phase will remain after bonding.

A low temperature (approximately 200° C. or lower) pressure bond, as represented by arrows 42 in FIG. 3, is then used to form a bonded layer 44 from the multi-layer metal bond interface 34. In one embodiment, the donor substrate 30 and acceptor substrate 34 are brought together under a moderate pressure of less than 10 MPa, preferably approximately 4 MPa within a nitrogen ambient. The temperature is then raised slightly above the melting point of the lowest melting temperature metal. In this example, In has the lowest melting temperature, with a melting temperature of approximately 156° C. Bonding is then performed at approximately 200° C. and the selected multi-layer metal bond interface 44 is formed between the thin film 32 and the acceptor substrate 34, as shown in FIG. 3.

In this example, the layer 44 is the compound $PdIn_3$. This layer 44 is a mechanically stable bond with a melting point of 664° C. The bonding time is selected to allow complete reaction of the metal multi-layers to form the desired new phase.

Returning to FIG. 2, the next processing step is to irradiate the thin film 32 through the donor substrate 30 to form an interfacial layer (step 50). Arrow 52 in FIG. 4 represents irradiated energy applied to the donor substrate 30. This operation is described in detail in the related application entitled "Separation of Thin Films from Transparent Substrates by Selective Optical Processing", U.S. Ser. No. 09/012,829, filed Jan. 23, 1998, which is incorporated by reference herein. In short, this step applies irradiated light of a wavelength that is substantially more strongly absorbed in the thin film 32 than in the donor substrate 30. This results in the formation of an interfacial layer between the thin film 32 and the donor substrate 30. FIG. 4 illustrates the resultant interfacial layer 54 produced between the thin film 32 and the donor substrate 30.

The remaining steps illustrated in FIG. 1 are also described in the cited application, thus they are only discussed briefly herein. FIG. 1 illustrates that the next processing step is to sever the interfacial layer to separate the donor substrate 30 from the acceptor substrate 34 (step 60). The resultant structure is shown in FIG. 5. The thin film may then be cleaned (step 62). The cleaned film may then be lifted from the acceptor substrate (step 64) or it may be used as a growth substrate for new epitaxial growth (step 66).

In sum, most of the steps of FIG. 1 are consistent with the technology described in the previously cited application. The present invention departs from the previous technology in that a multi-layer metal bond interface is used to link the acceptor substrate 34 to the thin film 32. The formation of a low temperature metal bond in the disclosed manner is believed to be inventive. The donor substrate 30 removal process and subsequent processing described in connection with steps 50–66 of FIG. 1 may be used in accordance with the low temperature metal bond formation technique of the invention. However, other lift-off techniques may also be used in accordance with the low temperature metal bond formation technique of the invention.

FIG. 6 illustrates criteria that may be used to implement the step of selecting a multi-layer metal bond interface (step 24). The first step shown in FIG. 6 is to select a new multi-layer metal bond interface (step 80). It is then determined whether the bonding over-layer has a low resistance to shear stress at temperatures below 200° C., such that sub-micron surface asperities and particulates do not prevent full surface contact (step 82). As defined herein, a low resistance to shear stress means that the metal melts and flows to maximize contact area. This property makes the bond less susceptible to failure due to sub-micron and surface roughness, thus improving the yield of the bonding process.

If the selected multi-layer metal bond interface does not satisfy this criteria, a new multi-layer metal bond interface is selected at step 80. If the selected multi-layer metal bond interface does satisfy this criteria, it is determined whether the bonding under-layer will adhere to the donor and acceptor substrates (step 84). If not, a new multi-layer metal bond interface is selected at step 80; if so, it is determined whether the bonding over-layer and under-layer will form a new bonded layer (step 86). If a new layer will not be formed, then a different multi-layer metal bond interface is selected at step 80.

If a new layer will be formed, the condition at step 88 should be satisfied, namely, that the low temperature bonding process at or below approximately 200° C. will not produce a low melting point phase or residue. Elimination of the low melting point phase or residue by reaction with the other metallic constituents, after full contact is achieved permits subsequent processing at 200° C. or higher temperatures. If this condition is not satisfied, then a new multi-layer metal bond interface is selected at step 80. If this condition is satisfied, the condition of step 90 is considered. Step 90 determines whether the new bonded layer has low contact resistance. In the case of a wide gap semiconductor, such as GaN, low contact resistance means a specific contact resistance of no greater than $10^{-4}$ Ohm-cm$^2$. In the case of a conventional semiconductor, low contact resistance means a specific contact resistance of no greater than $10^{-6}$ Ohm-cm$^2$. In the case of a metal, low contact resistance means a specific contact resistance of no greater than $10^{-7}$ Ohm-cm$^2$.

Step 90 also determines whether the bonded layer has low thermal resistance. As used herein, low thermal resistance refers to a thermal conductivity of no lower than 10 Watts/m°K. If the conditions of step 90 are not satisfied, a new multi-layer metal bond interface is selected at step 80. If the conditions are satisfied, a final condition is tested at step 92, namely, whether the new bonded layer will be thinner than the film. This condition is tested so that the properties of the new bonded layer do not dominate those of the film. If this condition is satisfied, the selected multi-layer metal bond interface is used (step 94) in accordance with the processing shown in FIG. 1.

Although the invention has been fully described, the invention may be more fully appreciated in connection with a more specific example. The invention has been implemented with a GaN thin film 32 of approximately 3 $\mu$m on a double-sided polished sapphire donor substrate 30. A thin bilayer of Ti—Pd (5 nm and 100 nm thickness of Ti and Pd, respectively) was deposited onto the GaN by electron beam (e-beam) evaporation (base pressure of approximately $1\times10^{-7}$ Torr). The thin bilayer thereby forming the donor bonding under-layer 38. The acceptor substrate 34 was separately coated with a 100 nm thick e-beam evaporation Pd film, forming the acceptor bonding under-layer 35. An approximately 1000 nm In bonding over-layer 40 is then deposited on the donor bonding under-layer 38.

The Pd and In thicknesses were chosen such that the ratio of the Pd:In was maintained between 1:3 and 1:1 to insure complete consumption of the In during the low temperature bonding process. The GaN/sapphire structures were then bonded at a pressure of approximately 2.8 Mpa onto boron doped p-type Si (001), semi-insulating GaAs (001) or polymide substrates at 200° C. for 30 minutes in a flowing nitrogen ambient. In an embodiment of the invention, an inert metal layer (e.g., 1–10 nm of Ti) is placed as a diffusion barrier between Pd and In to delay the completion of the reaction at 200° C.

During the initial stage of the bonding, as the temperature exceeds the In melting point of approximately 156° C., molten In flows laterally to fill in any voids and encase submicron particulates and surface asperities, thus maximizing the contact area of the bond. The Pd+3In to $PdIn_3$ reaction begins at room temperature and is completed during the 200° C. treatment. The resulting $PdIn_3$ bond is strong enough to withstand the subsequent thermal and mechanical shock from the laser lift-off process (step 50 of FIG. 1).

All laser processing of the sapphire/GaN/Pd—In/receptor-substrate structures was performed in air using a Lamda Physik Lextra 200 KrF pulsed excimer laser (38 ns pulse width). The decomposition of the interfacial GaN into Ga metal and $N_2$ gas was accomplished with a single 600 mJ/cm$^2$ laser pulse directed through the transparent sapphire substrate. By melting the thin Ga rich interfacial layer ($T_m$=30° C.) after laser irradiation, lift-off, and transfer of the GaN film from sapphire onto the receptor substrate was completed. In using this two-step process, GaN films up to 20 cm$^2$ were successfully transferred by rastering a 0.03 cm$^2$ beam spot across the entire sample. A thin Ga rich layer on the surface of the exposed interface was easily removed with a 1:1 solution of HCl and de-ionized water. The transferred films were then characterized by x-ray diffraction, scanning electron microscopy, and atomic force microscopy to verify the structural integrity of the GaN film before and after lift-off and transfer.

Those skilled in the art will recognize a number of benefits associated with the invention. The primary impediment to implementing GaN technology is the lack of a lattice-matched substrate for GaN growth. This impediment necessitates heteroepitaxy on available but dissimilar substrates, such as sapphire and SiC. Furthermore, the incongruent decomposition of this compound at relatively low temperatures to produce metallic Ga and $N_2$ gas prevents the commercial feasibility of growing large bulk crystals and inhibits efforts to grow high quality thin films.

GaN based optoelectronic and electronic devices have been previously demonstrated on sapphire. However, device quality GaN material on substrates other than sapphire has not met with much success. The symmetry of the GaN crystal structure (hexagonal wurtzite structure), combined with the high GaN thin film growth temperatures prevent growth of high-quality material directly onto more common substrates, such as GaAs, InP or Si, thus impeding the direct integration of GaN with existing electronic and optoelectronic semiconductor technologies. Bulk GaN substrates are currently being investigated, but crystal size is limited to less than a few square centimeters.

GaN thin films grown on sapphire substrates exhibit pronounced roughness due in part to the large density of dislocations intersecting the film surface. Hence, direct bonding of the GaN/sapphire structures onto dissimilar substrates presents a formidable challenge. The use of a transient liquid phase to accommodate surface roughness by spreading laterally to fill voids has been shown to successfully join ceramic materials for high temperature applications. Of the low melting point metals, indium is a metal which liquefies above room temperature (above approximately 25° C.) for processing stability and below 200° C., thereby permitting bonding to a wide range of substrates including semiconductors, metals, glass, polymers and electro-ceramics. Melting the indium metal at 156° C. allows the metal to re-flow and fill in around surface asperities, thus accommodating rough surfaces. It is also known that palladium is adherent to most semiconductors and polymers, thus the Pd—In system is applied for low temperature bonding in which the compound $PdIn_3$ is the first phase to form at a Pd—In diffusion couple. Palladium is also optimal due to its resistance to oxidation. The resulting $PdIn_3$ phase also has a relatively high melting point of 664° C., thus, the Pd—In intermetallics are able to yield a stable high temperature $PdIn_3$ bond from a low temperature bonding process. Furthermore, the Pd—In system is an ideal bonding material due to its uniform native-oxide penetration, and limited and uniform semiconductor consumption, when in direct contact with a semiconductor.

The bonding process described, in conjunction with an optical lift-off process, allows for novel heterostructure stacking combinations of the GaN material system with other materials not possible by typical growth methods. GaN thin films can also be combined with other substrate materials more common in electronic and optoelectronic applications, such as Si or GaAs. The integration of GaN based materials with AlGaAs or AlInGaP on GaAs substrates allows for arrays of microscopic red, green and blue light emitting diodes on angle GaAs wafer for color display applications. GaN thin films can also be bonded to substrates of higher electrical and thermal conductivity than sapphire, thereby improving device performance by minimizing electrical series resistance and improving heat transfer from the active region.

The foregoing description, for purposes of explanation, used specific nomenclature to provide a thorough understanding of the invention. However, it will be apparent to one skilled in the art that the specific details are not required

in order to practice the invention. In other instances, well known circuits and devices are shown in block diagram form in order to avoid unnecessary distraction from the underlying invention. Thus, the foregoing descriptions of specific embodiments of the present invention are presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, obviously many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.

What is claimed is:

1. A method of forming a low temperature metal bond, comprising the steps of:

providing a donor substrate;

growing a thin film on a surface of said donor substrate;

supplying an acceptor substrate;

selecting a multi-layer metal bond interface for positioning between said thin film and said acceptor substrate; and

forming, at a temperature below approximately 200° C., a bonded layer between said thin film and said acceptor substrate from said multi-layer metal bond interface.

2. The method of claim 1 wherein said providing step includes the step of providing a crystallographically oriented donor substrate.

3. The method of claim 2 wherein said providing step includes the step of providing a sapphire donor substrate.

4. The method of claim 2 wherein said providing step includes the step of providing a MgO donor substrate.

5. The method of claim 2 wherein said providing step includes the step of providing a quartz donor substrate.

6. The method of claim 1 wherein said providing step includes the step of providing a fused silica donor substrate.

7. The method of claim 1 wherein said growing step includes the step of growing a GaN thin film on said donor substrate.

8. The method of claim 1 wherein said supplying step includes the step of supplying a Si acceptor substrate.

9. The method of claim 1 wherein said supplying step includes the step of supplying a GaAs acceptor substrate.

10. The method of claim 1 wherein said supplying step includes the step of supplying a polymer substrate.

11. The method of claim 10 wherein said supplying step includes the step of supplying a polyimide substrate.

12. The method of claim 1 wherein said selecting step includes the step of selecting a multi-layer metal bond interface with a bonding over-layer with low resistance to shear stress.

13. The method of claim 1 wherein said selecting step includes the step of selecting a multi-layer metal bond interface with a bonding under-layer that adheres to said donor substrate and said acceptor substrate.

14. The method of claim 1 wherein said selecting step includes the step of selecting a multi-layer metal bond interface with a bonding over-layer and bonding under-layer that will from a new bonded layer.

15. The method of claim 1 wherein said selecting step includes the step of selecting a multi-layer metal bond interface that produces a bonded layer with low contact resistance and low thermal resistance.

16. The method of claim 1 wherein said selecting step includes the step of selecting a multi-layer metal bond interface that produces a bonded layer that is thinner than said thin film.

17. The method of claim 1 wherein said selecting step includes the step of selecting a Pd—In multi-layer metal bond interface.

18. The method of claim 1 wherein said selecting step include the step of selecting a donor bonding under-layer comprising Ti and Pd, selecting an acceptor bonding under-layer comprising Pd, and selecting a bonding over-layer comprising In.

19. The method of claim 1 further comprising the step of irradiating said thin film through said donor substrate to form an interfacial layer.

20. The method of claim 18 further comprising the step of severing said interfacial layer to separate said donor substrate from said acceptor substrate.

21. The method of claim 20 further comprising the step of detaching said thin film from said acceptor substrate.

22. The method of claim 20 further comprising the step of growing a new epitaxial growth on said thin film.

23. A method of bonding a film disposed on a first substrate to a second substrate, comprising:

disposing a first bonding layer on said film, said first bonding layer comprising a first material having a first melting point;

forming a second bonding layer on said second substrate, said second bonding layer comprising a second material having a second melting point; and

annealing, at a temperature above a lower one of said first melting point and said second melting point, said first bonding layer and said second bonding layer to form a bonded layer between said film and said second substrate, wherein said bonded layer has a third melting point that is above said lower one of said first melting point and said second melting point.

24. The method of claim 23, wherein the second bonding layer comprises the first material.

25. The method of claim 23, wherein said disposing comprises depositing a bilayer of Ti—Pd onto said film.

26. The method of claim 25, wherein said depositing comprises depositing an approximately 5 nm thick layer of Ti and a 100 nm layer of Pd.

27. The method of claim 23, wherein said forming comprises depositing a layer of Pd and a layer of In onto said second substrate.

28. The method of claim 23, wherein said forming comprises depositing an approximately 100 nm thick layer of Pd onto said second substrate by electron beam evaporation.

29. The method of claim 28, wherein said forming comprises depositing an approximately 1000 nm thick layer of In onto said layer of Pd.

30. The method of claim 23, wherein said annealing comprises coupling said first bonding layer to said second bonding layer at a pressure of approximately 2.8 Mpa.

31. The method of claim 23, wherein said annealing comprises coupling said first bonding layer and said second bonding layer at a temperature below approximately 200° C.

* * * * *

US006507467B1

# (12) United States Patent
Schadewald, Jr. et al.

(10) Patent No.: US 6,507,467 B1
(45) Date of Patent: Jan. 14, 2003

(54) COMB SHUNT FOR ESD PROTECTION

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(73) Assignee: Seagate Technology LLC, Scotts Valley, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 151 days.

(21) Appl. No.: 09/640,422

(22) Filed: Aug. 17, 2000

Related U.S. Application Data

(60) Provisional application No. 60/149,529, filed on Aug. 17, 1999.

(51) Int. Cl.[7] ................................................ G11B 5/52

(52) U.S. Cl. .................................... 360/323; 360/245.8

(58) Field of Search ............................. 360/323, 244.1, 360/245.8, 246, 264.2, 266.3

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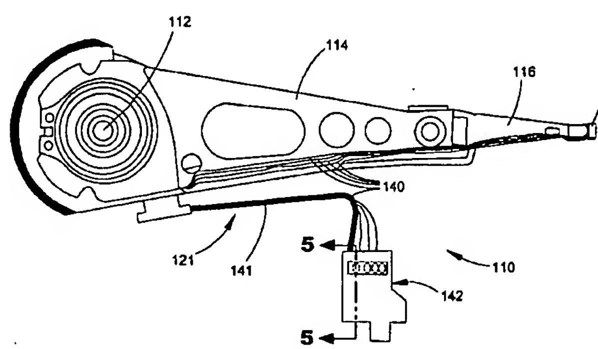
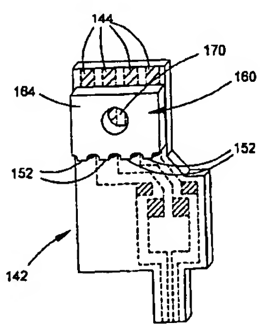
(74) *Attorney, Agent, or Firm*—Merchant & Gould P.C.

(57) ABSTRACT

An apparatus for protecting a magnetoresistive head from electrostatic discharge. The apparatus includes an actuator assembly including the magnetoresistive head, and a connector board including a plurality of conductive traces in electrical contact with the magnetoresistive head. The connector board defines a plurality of openings therein, each of the openings having sides surfaces in electrical contact with one of the traces. The apparatus further includes a conductive shunting member including a plurality of protruding members adapted to be inserted into the openings and contact the side surfaces of the openings. The shunting member, when so inserted into the openings shorts the traces to provide protection of the magnetoresistive head from electrostatic discharge.

19 Claims, 5 Drawing Sheets

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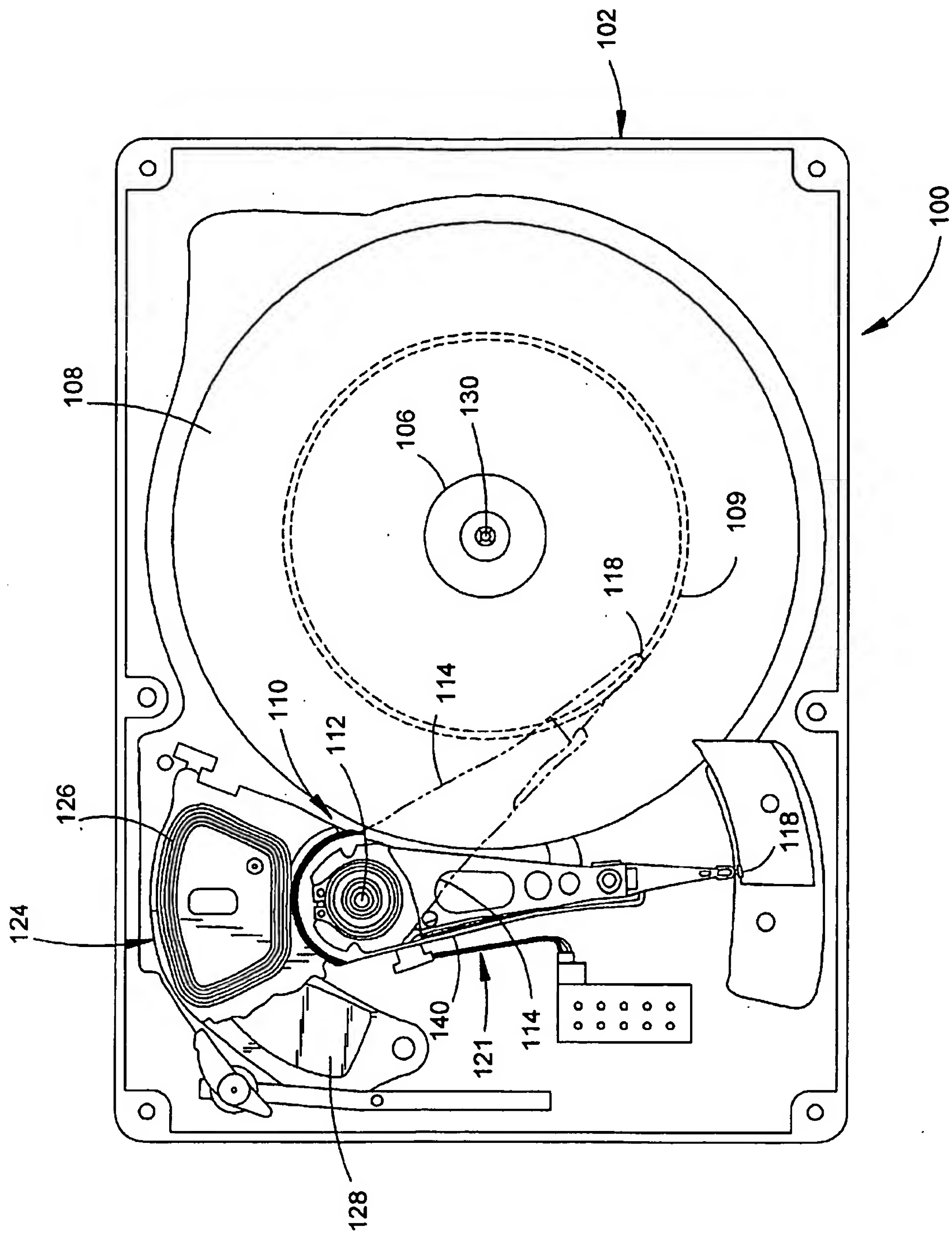
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FIG. 1

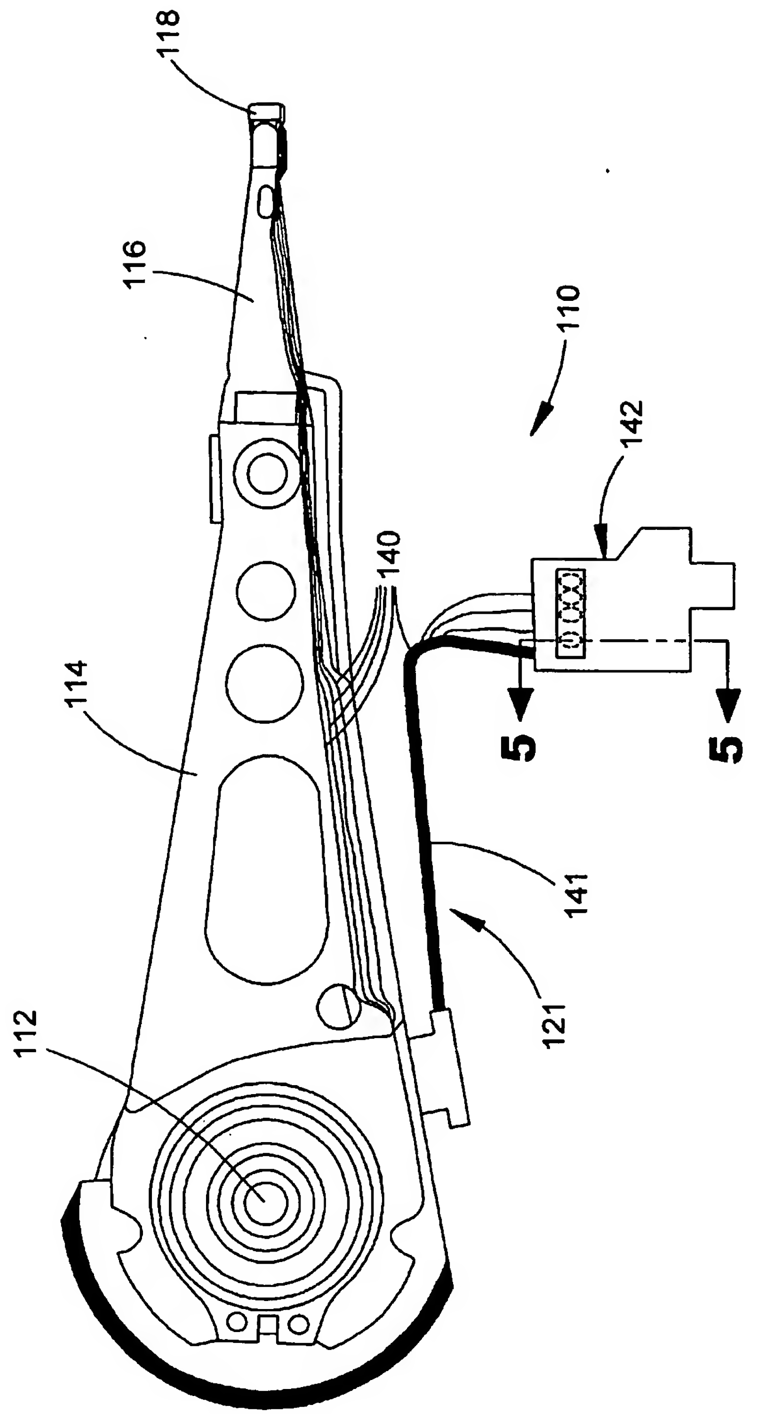


FIG. 2

FIG. 3

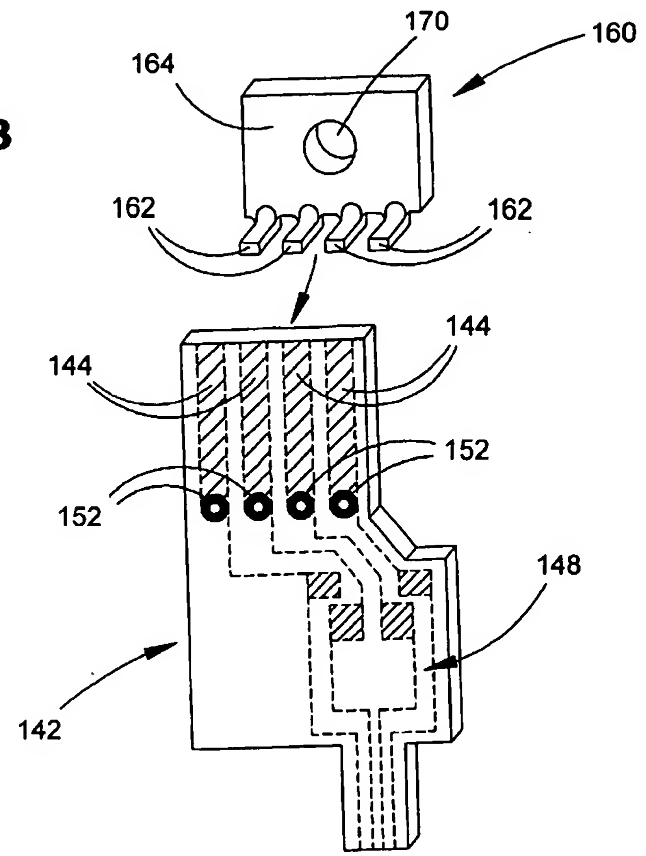
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FIG. 4

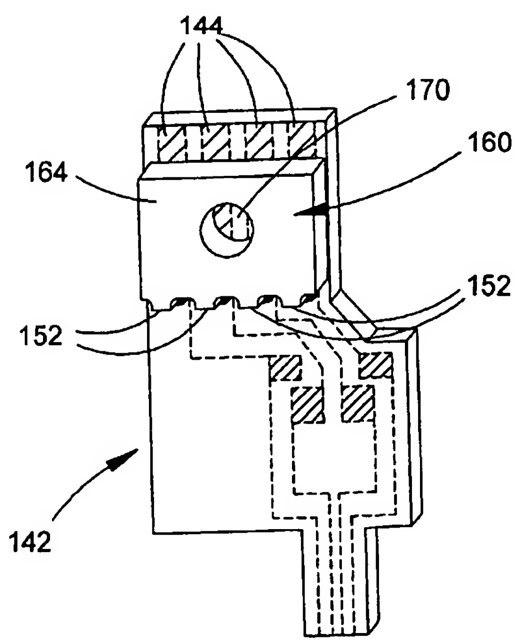
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FIG. 5

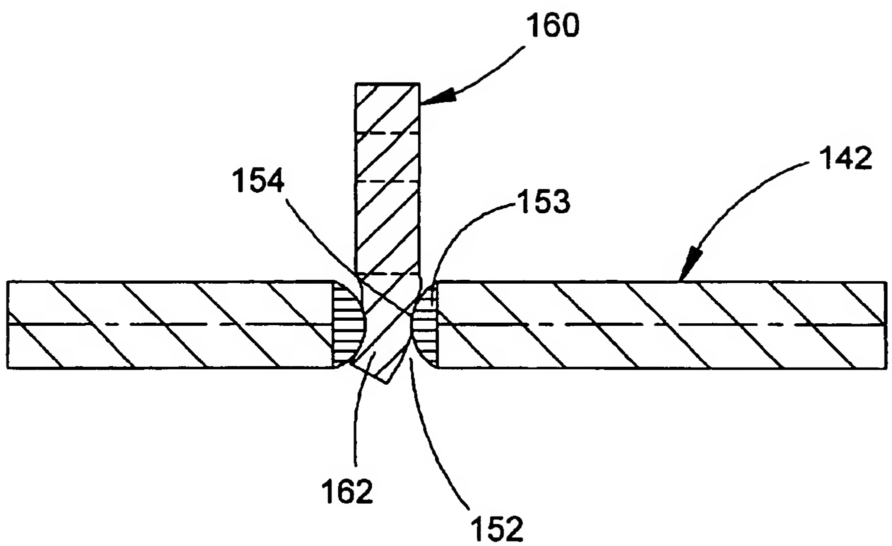
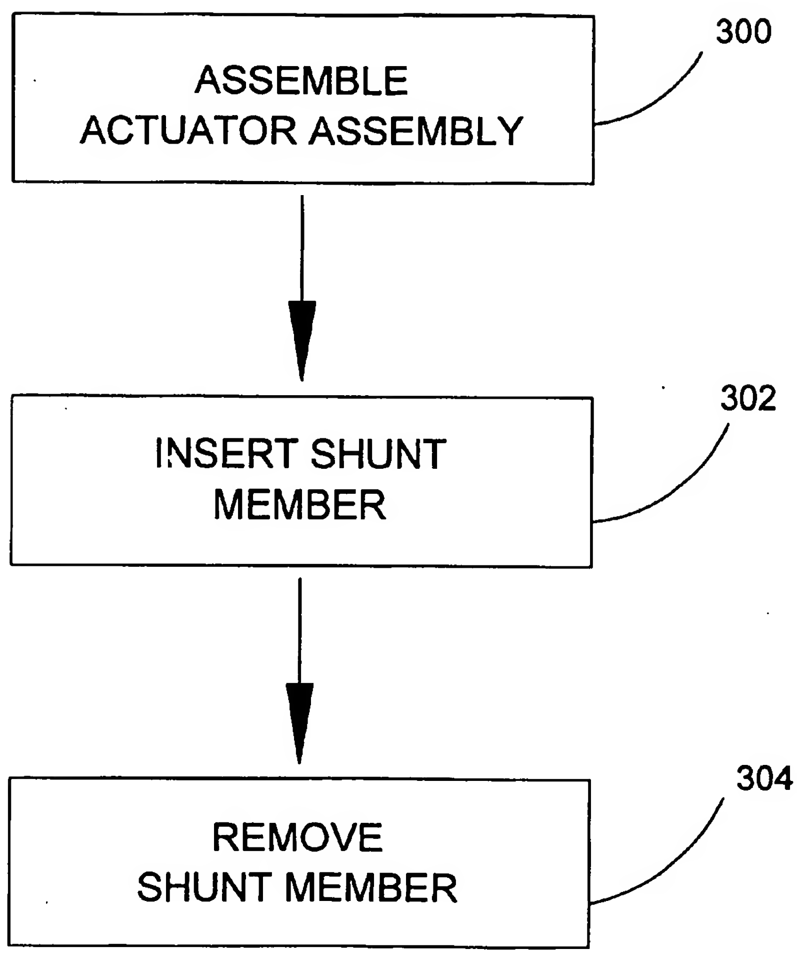


FIG. 6


ASSEMBLE ACTUATOR ASSEMBLY
300
INSERT SHUNT MEMBER
302
REMOVE SHUNT MEMBER
304

## COMB SHUNT FOR ESD PROTECTION

### RELATED APPLICATIONS

This application claims the priority of U.S. Provisional Patent Application Ser. No. 60/149,529 entitled "COMB PADDLEBOARD ESD SHUNT" filed Aug. 17, 1999.

### FIELD OF THE INVENTION

This application relates to magnetic disc drives and more particularly to the protection of magnetoresistive head structures from damage caused by electrostatic discharge.

### BACKGROUND OF THE INVENTION

Disc drives are data storage devices that store digital data in magnetic form on a storage medium on a rotating information storage disc. Modern disc drives include one or more rigid discs that are coated with a magnetizable medium and mounted on the hub of a spindle motor for rotation at a constant high speed. Information is stored on the discs in a plurality of concentric circular tracks typically by an array of transducers ("heads") mounted to a radial actuator for movement of the heads relative to the discs. Each of the concentric tracks is generally divided into a plurality of separately addressable data sectors. The read/write transducer, e.g., a read/write head, is used to transfer data between a desired track and an external environment. During a write operation, data is written onto the disc track and during a read operation the head senses the data previously written on the disc track and transfers the information to the external environment.

The heads are mounted on a portion of an actuator assembly via flexures at the ends of a plurality of actuator arms that project radially outward from an actuator body. The actuator body pivots about a shaft mounted to the disc drive housing at a position closely adjacent the outer extreme of the discs. The pivot shaft is parallel with the axis of rotation of the spindle motor and the discs, so that the heads move in a plane parallel with the surfaces of the discs. The actuator assembly further includes a series of lead wires that are in electrical contact with leads from the heads down the actuator arm to connect the heads to the disc drive circuitry such that the information can be transferred.

Trends in the disc drive industry have required disc drive manufacturers to provide drives with increased areal densities. In order to meet this growing demand, many advancements in read/write head technology have been implemented. One such advancement was moving from an inductive head design to a magnetoresistive (MR) head structure due to the many advantages a MR head offers.

Although there are many benefits with MR technology, there is one distinct problem. An MR head is 100 times more sensitive to electrostatic discharge (ESD) than the older inductive heads. Furthermore, since their introduction, MR head structures have shrunk in order to meet growing areal density demands, making the MR heads even more sensitive to ESD. The latest MR head technology, called GMR (Giant Magnetoresistive), is sensitive to ESD levels as low as 3 volts, and below.

ESD is an uncontrolled static charge transfer from one object to another. In MR heads, ESD occurs when there is a buildup of charge on various elements of the head or other elements in the read/write assembly that are in electrical contact with the MR element of the head, and the head is momentarily shorted to ground. The charge runs through the MR element into ground, thus creating an ESD pulse that is potentially damaging for the MR element.



ESD is only a minor concern in a completed, and operational disk drive. Once in a completed disc drive, the MR elements on the heads are typically protected. The drive case shields the heads from particulate contamination, human contact and other adverse elements that could cause an ESD event.

However, ESD presents a major problem during manufacture, installation and handling of the head and drive, because drive-level ESD protective measures are not yet in place. Therefore, ESD from human or equipment contact and electric fields can cause damage to the MR structures in the head, thereby reducing effect yield and raising costs.

Because of this constant potential damage to the head from ESD during manufacturing and handling, a method is desired which will protect the head from ESD damage. One such method of MR head protection is by shorting together the leads that connect the head contacts. By shorting the head leads, a low resistance path to ground exists. Therefore, the ESD pulse is directed through the short and bypasses the MR structure, thereby protecting the head.

However, when the head is required to function, the electrical shunt will also short out any electrical output from the head. Therefore, a method is required to not only apply the shunt during the manufacturing and building process, but also remove the shunt from the head during electrical testing and final installation of the head in the disk drive.

Many shunting devices and methods used in the art are complex, extensive, difficult to install and remove, and do not allow for the repeated application and removal of the shunt. Therefore, there is a need in the relevant art to overcome the shortcomings of the traditional ESD protection mechanisms.

### SUMMARY OF THE INVENTION

Against this backdrop the present invention has been developed. The present invention is an apparatus and method for providing ESD protection for a MR head.

In accordance with one preferred embodiment, the invention can be implemented as an apparatus for protecting a head from electrostatic discharge. The apparatus includes a connector board including a plurality of conductive traces in electrical contact with the head. The connector board defines a plurality of openings therein, each of the openings being in electrical contact with one of the traces. The apparatus further includes a shunting member including a plurality of protruding members adapted to be inserted into the openings such that the shunting member shorts the traces to provide protection of the head from electrostatic discharge.

The invention can be implemented in accordance with another preferred embodiment as simply the shunting member for protecting a head of an assembly from electrostatic discharge. As environment, the magnetoresistive assembly includes a plurality of conductive traces in electrical contact with the head. The shunting member includes a conductive body portion, and a plurality of protruding conductive members in electrical contact with and extending from the body portion. The protruding members are adapted to contact the conductive traces of the assembly to short the traces to provide protection of the head from electrostatic discharge.

The shunting member, and apparatus and methods, of some embodiments of the invention provide many advantages. In some embodiments, the shunting apparatus is easily and quickly applied and removed. The time it takes to apply the shunt is often on the order of seconds, and removal can be even quicker. This means that the shunt will not signifi-

cantly delay production or testing. Because the shunting apparatus and method of this invention do not involve hard bonded or soldered shunts like some other methods, application and removal of the shunt can be completed numerous times. This is advantageous for head re-testing and for end-users who do not possess the capability of outfitting their facility with special shunt removal equipment. In some embodiments, the only equipment necessary to apply or remove the shunt is a tweezers or similar device to insert or remove the shunt member from openings in the connector board.

These and various other features as well as advantages which characterize the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings. The embodiments of the invention disclosed herein are to be considered merely as illustrative, and the invention is limited in scope only as specified in the appended claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view of a disc drive, with its top cover removed, including an actuator assembly incorporating ESD protection features in accordance with one preferred embodiment of the invention.

FIG. 2 is a top view of the actuator assembly shown in FIG. 1.

FIG. 3 is a perspective view of the connector board of the actuator assembly of FIG. 2, showing the shunting assembly in an un-shunted position.

FIG. 4 is a perspective view of the connector board of the actuator assembly of FIG. 2, showing the shunting assembly in a shunted position.

FIG. 5 is a sectional view of the connector board of FIG. 2 taken along lines 5—5 in FIG. 2.

FIG. 6 is a flow chart showing the steps for using the shunting assembly in accordance with a preferred embodiment of the present invention.

## DETAILED DESCRIPTION

The invention provides ESD protection for MR elements on an MR head by shorting or "shunting" the electrical leads to the head by the use of a novel shunting apparatus and method. It should be understood that as used herein, the terms "magnetoresistive" or "magnetoresistive elements" are intended to include both magnetoresistive ("MR") and giant magnetoresistive ("GMR") elements.

As environment for an actuator assembly 110 incorporating ESD protection features in accordance with one preferred embodiment of the invention, FIG. 1 is a top view of a disc drive 100. The disc drive 100 includes a base plate 102 to which various components of the disc drive 100 are mounted. A top cover (not shown) cooperates with the base 102 to form an internal, sealed environment for the disc drive 100 in a conventional manner. The components include a disc drive motor 106 that rotates one or more information storage discs 108 at a constant high speed. The disc drive spindle motor 106, rotates a spindle 130 on a bearing sleeve (not shown). The spindle 130 carries the one or more information storage discs 108. The spindle 130, and therefore the one or more information storage discs 108, are rotated about the spindle axis of rotation by the spindle motor 106, as is generally known in the art.

Information is written to and read from tracks 109 on the disc 108 through the use of the actuator assembly 110 which rotates about a bearing shaft assembly 112 positioned adjacent the discs 108. The actuator assembly 110 includes an actuator arm 114 which extend towards the disc 108, with one or more flexures 116 extending from the actuator arm 114. Mounted at the distal end of each of the flexures 116 is a head 118 that includes an air bearing slider (not shown) enabling the head 118 to fly in close proximity above the corresponding surface of the associated information storage disc 108. The slider typically houses the MR element, the write element, and pads, which provide electrical contact to these elements. The actuator assembly 110 further includes connection circuitry 121 including electrical connectors 140 and a connector board 142 that interconnects the head 118 with the circuitry of the disc drive 110.

The radial position of the heads 118 is controlled through the use of a voice coil motor (VCM) 124, which typically includes a coil 126 attached to the actuator assembly 110, as well as one or more permanent magnets 128 that establish a magnetic field in which the coil 126 is immersed. The controlled application of current to the coil 126 causes magnetic interaction between the permanent magnets 128 and the coil 126 so that the coil 126 moves in accordance with the well-known Lorentz relationship. As the coil 126 moves, the actuator assembly 110 pivots about the bearing shaft assembly 112 and the heads 118 are caused to move across the surfaces of the discs 108.

It will be understood by those of skill in the art that the invention relates to an ESD shunting apparatus and method that is used primarily during the construction and installation of the actuator assembly 110. The above description of a disc drive 100 incorporating such an actuator assembly 110 is provided for environment. It should be understood that the invention is in no way limited to shunting of actuator assemblies 110 that are for use only in a disc drive. Actuator assemblies incorporating the shunting apparatus and method of the invention are often used in other applications, such as media testing devices, and other such applications.

FIG. 2 is a top view of the actuator assembly 110 incorporating ESD protection features in accordance with one preferred embodiment of the invention. The actuator assembly 110 includes the actuator arm 114, the flexure 116, and an MR head 118 mounted at the distal end of the flexure 116. The term "MR head" denotes an integrated unit that preferably includes an inductive write element and an MR read element. However, this does not exclude application of the invention to an actuator assembly 110 including a read head that includes only an MR read element. Furthermore, the ESD protection features of the invention may be applied to actuator assemblies including other types of recording heads, such as non-MR heads.

The actuator assembly 110 further includes connection circuitry 121 that interconnects the head 118 with the circuitry of the device in which the actuator assembly will be used, for example, a disc drive 110, or a media testing device (not shown). The connection circuitry 121 includes electrical connectors 140 which extend between the magnetoresistive elements of the head 118, as well as any additional reading or writing sensor/transducers, and a connector board 142. The electrical connectors 140 are preferably lead wires 140 made of electrically conductive material, such as copper, or other such conductive material. The lead wires 140 are connected to various components of the MR head 118. Preferably, the wires are electrically connected to relatively large conductive pads (not shown) on the MR head 118. Such pads are typically connected to the small MR head elements (not shown).

The lead wires 140 run from the head 118, along the flexure 116 and the actuator arm 114, and thereafter off of the

actuator arm **114**, and to the connector board **142**. The wires **140** are preferably affixed to the flexure **116** and the actuator arm **114** using techniques generally known in the art, for example, by the use of anchors or adhesives, and the like. The lead wires **140** can be held together by a tubular sheath, configured as a wire bundle, or arranged in another similar manner. Preferably, the portion **141** of the lead wires **140** that extend off of the actuator arm **114** and to the connector board **142** are held together by a sheath, or are incorporated into cable, such as a ribbon cable, flex cable, or other such structure.

Referring to FIGS. **3** and **4**, the connector board **142** includes MR head traces **144** that are adapted to receive, and make electrical contact with, the lead wires **140** to provide a signal path between the MR head **118** and the connector board **142** via the lead wires **140**. The traces **144** of the connector board **142** are in turn in electrical contact with additional electrical circuitry **148** of the connector board **142**. The additional circuitry **148** of the connector board **142** is adapted to mate with and electrically connect the actuator assembly **110** with the circuitry of the device in which the actuator assembly will be used, for example, a disc drive **100**, or a testing device (not shown). Many known connector board designs and arrangements can be used.

A shunting apparatus is incorporated onto the connector board **142** to protect the MR head elements from ESD during assembly, installation and handling of the actuator assembly **110**. The shunting apparatus includes a plurality of openings **152** in the connector board **142**. The openings **152** are arranged such that they extend through the middle of the traces **144**. In the embodiment shown, there are four traces **144** and therefore four openings **152**, respectively. However, those of skill in the art will recognize that in other embodiments, additional or fewer traces and additional or fewer openings can be used, depending upon the number of leads entering the connector board, and the desired shunting activity. Preferably, the diameter of each of these openings **152** is of such a size that protruding members **162** of a shunting member **160** can snugly engage the inner peripheral surfaces **154** of the openings **152**, as will be discussed in more detail below. (FIG. **5**). A portion of, or the entire inner peripheral surface **154** of, each of the openings **152** includes a conductive material that is in electrical contact with the traces **144**. Preferably, annular rings **153** made of a conductive material, such as gold, are used as the inner peripheral surfaces **154** of the openings **152**. Preferably, the annular rings are generally hour glass in cross sectional shape, and are inserted into each of the openings **152** to provide the requisite conductive material surfaces **154** in electrical contact with the traces **144**.

The shunting apparatus further includes a shunting member **160**. The shunting member **160** includes a top support portion **164**, and a plurality of downwardly extending portions **162**. Preferably, the shunting member **160** resembles a comb, with a row of protruding members **162**, or "teeth" jutting from a common support member **164**. In the embodiment shown, there are four protruding members **162**, but those of skill in the art will recognize that additional or fewer protruding members can be used, depending upon the number of traces to be shunted, and the desired shunting activity. The protruding members **162** are spaced apart, and aligned such that each member **162** can be aligned with an opening **152** in the connector board **142**. Preferably, the protruding members **162** are slightly bent in shape to provide a certain degree of spring tension with the inner surfaces **154** of the openings **152** when inserted. An opening **170** can be made through the top support portion **164** of the shunting member **160** to provide for easy engagement of the shunting member **160** with a tool, such as a tweezers (not shown), for easy insertion and removal of the shunting member **160** from the connector board **142**. The shunting member **160** will act as the shorting path between electrical traces **144** on the connector board **142**. Therefore, the shunting member **160** is made from an electrically conductive material, such as beryllium copper, phosphorus bronze, or other such conductive material.

Referring to FIG. **4**, to utilize the shunting characteristic of this apparatus, the protruding portions **162** of the shunting member **160** are inserted into the openings **152** in the connector board **142** such that the protruding portions **162** are in electrical contact with the inner peripheral surfaces **154** of the openings **152**. Now, the electrical traces **144** in the connector board **142** are short circuited, or "shunted" through the shunting member **160**. Because the connector traces **144** are shunted, and are electrically connected to the head **118**, a shorting path away from the head **118** is made. This path runs through the connector traces **144**, through the conductive material on the surface **154** of the openings **152** and through the conductive shunt member **160**. In this way, ESD pulses will be shunted through the shunt member **160** away from the head **118**, and the MR elements in the head **118** are protected from ESD.

FIG. **6** is a flow diagram showing the steps for a shunting method in one preferred embodiment of the present invention. In operation **300**, the actuator assembly **110** is manufactured and assembled including the actuator arm **114**, the flexure **116**, the MR head **118**, and connection circuitry including electrical connectors **140** and a connector board **142**. The connector board **142** includes the MR head traces **144**, and the plurality of openings **152** having peripheral surfaces in electrical contact with the traces **144**. In operation **302**, the protruding portions **162** of the shunting member **160** are inserted into the openings **152** in the connector board **142** such that the protruding portions **162** are in electrical contact with the inner peripheral surfaces **154** of the openings **152**, and the electrical traces **144** in the connector board **142** are short circuited, or "shunted" through the shunting member **160**. After shunting, the actuator assembly **110** can be optionally further processed, manufactured, stored, cleaned, installed in a device, or the like, while avoiding EDS that may damage the MR head. In operation **304**, the shunting member **160** is removed from the openings **152** in the connector board **142**, and the actuator can be tested or placed into operation. Thereafter, steps **302** and **304** can be repeated, as necessary, to attach and remove the shunting member as desired.

It will be clear that the present invention is well adapted to attain the ends and advantages mentioned as well as those inherent therein. While presently preferred embodiments have been described for purposes of this disclosure, numerous changes may be made which will readily suggest themselves to those skilled in the art. For example, the embodiments described above involve four traces in a connector board being shunted by a shunting member including four projecting members. Those of skill in the art and others will understand that additional or fewer traces can be shunted using a shunting apparatus having additional or fewer openings in the connector board, and a shunting member with additional or fewer projecting members. Additionally, more than one shunting member can be used on a connector board, dictated only by the desired shunting activity. Many other such modifications, changes and alternatives are also contemplated, and will be apparent to those of skill in the art. Accordingly, all such modifications,

changes and alternatives are encompassed in the spirit of the invention disclosed and as defined in the appended claims.

What is claimed is:

1. An apparatus for protecting a head from electrostatic discharge, the apparatus comprising:

a connector board including a plurality of conductive traces in electrical contact with the head, the connector board defining a plurality of openings therein, each of the openings being in electrical contact with one of the traces; and

a shunting member including a plurality of protruding conductive members adapted to be inserted into the openings, wherein the plurality of protruding conductive members are in electrical contact with a wall of the openings, and wherein further the walls of the openings are in electrical contact with the plurality of conductive traces, thereby providing an electrical path to short the traces to provide protection of the head from electrostatic discharge.

2. The apparatus of claim 1, wherein the openings include side surfaces, and the side surfaces of the openings are annular rings in electrical contact with the conductive traces.

3. The apparatus of claim 1, wherein the shunting member includes a body portion and four protruding members.

4. The apparatus of claim 1, wherein a connector board includes four conductive traces in electrical contact with the head, and the connector board defines four openings therein, each of the openings having sides surfaces in electrical contact with one of the traces.

5. The apparatus of claim 1, wherein the connector board is adapted to be connected to a media-testing device.

6. The apparatus of claim 1, wherein the connector board is adapted to be connected to a disc drive.

7. The apparatus of claim 1, wherein the head includes magnetoresistive elements.

8. The apparatus of claim 1, further including an actuator assembly connects to the connector board, the actuator assembly comprising an actuator arm, a flexure mounted to the actuator arm, and the head mounted at the distal end of the flexure.

9. The apparatus of claim 8, wherein a connector board includes four conductive traces in electrical contact with the head, and the connector board defines four openings therein, each of the openings having sides surfaces in electrical contact with one of the traces, and the shunting member includes a body portion and four protruding members each adapted to be inserted into one of the openings to shorts the traces.

10. The apparatus of claim 8, wherein the side surfaces of the openings are annular rings in electrical contact with the conductive traces.

11. The apparatus of claim 8, wherein the connector board and actuator assembly are adapted to be connected to a media-testing device.

12. A shunting member for protecting a head of an assembly from electrostatic discharge, the assembly including a plurality of conductive traces in electrical contact with the head, the shunting member comprising:

a conductive body portion;

a plurality of protruding conductive members in electrical contact with and extending from the body portion, the protruding members adapted to electrically engage a plurality of connector openings walls, wherein the walls of the openings are in electrical contact with the conductive traces of the assembly to short the traces to provide protection of the head from electrostatic discharge.

13. The shunting member of claim 12, wherein the shunting member includes four protruding members.

14. The shunting member of claim 12, wherein the shunting member is made of beryllium copper, phosphorus bronze, or mixtures thereof.

15. The shunting member of claim 12, wherein the protruding members are adapted to mate with openings in the assembly that are in electrical contact with the head.

16. The shunting member of claim 15, wherein the protruding members are resiliently urged in shape to provide a degree of spring tension with the inner surfaces of the openings when inserted.

17. The shunting member of claim 16, wherein the protruding members are bent in shape.

18. The shunting member of claim 12, wherein the assembly is a magnetoresistive assembly and the head is a magnetoresistive head.

19. An apparatus for protecting a magnetoresistive head from electrostatic discharge, the apparatus comprising:

an actuator assembly including a magnetoresistive head; and

means for shunting the magnetoresistive head to protect the head from electrostatic discharge, wherein the means are in electrical contact with a wall of an opening in a connector, which is in electrical contact with a plurality of conductive traces.

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